SNOWFALLS, FRESHETS, AND THE WINTER FLOW OF STREAMS IN THE STATE OF NEW YORK.

By Robert E. Horton, Hydrographer, U. S. Geological Survey. Dated Utica, N. Y., April 18, 1905.

In a region having a somewhat rigorous climate, as does New York, the conditions controlling stream flow in winter are greatly different from those pertaining to the summer months.

For summer periods, a knowledge of the depth and distribution of precipitation and of the temperature, wind, and relative humidity, the latter factors controlling evaporation losses, are sufficient to enable the run-off of streams during different years to be rationally compared and the main causes of their differences traced. Such data have been provided in the records of the U. S. Weather Bureau.

In order to reasonably analyze and compare the records of a stream for the winter periods of different years, much additional data are required which are not a matter of general record; for example—

(1) Dates between which the soil is frozen.
(2) Dates between which soil is snow covered.
(3) Successive depths of snow accumulations.
(4) Dates and general extent to which water surfaces within the watershed are frozen.
(5) A record of the depth and fluctuation of the level of the ground water horizon is also desirable in studying both winter and summer records.

Few systematic records of soil temperatures are kept in the winter. The date when frost permanently enters and leaves the ground can, however, be closely inferred from the air temperature records.

The water equivalent of loose freshly fallen snow is usually between one-seventh and one-twelfth. The difference in water equivalent between loose freshly fallen snow and compact accumulated snow should not be overlooked. The water equivalent of the layer of snow lying on the ground late in winter is very much greater than that of fresh fluffy snow; a fact which may be of some importance in predicting floods, although data on this point are surprisingly rare.

In the accompanying Table 1 the results of a valuable series of Prussian experiments are given. These are of practical interest from the fact that an attempt was made to separate the freshly fallen snow from the preceding accumulation. The average water equivalent for the total snow cover was found to be 15.26 per cent, and for the freshly fallen portion, 8.48 per cent. The snow cover came and went at frequent intervals, and in many instances the entire layer was freshly fallen. The total depth was usually but a few inches. The results probably represent with precision the water equivalent of a thin snow cover under the conditions described.

In Table 2 are given the results of experiments made in the New England States, chiefly in the years 1903 and 1904. In general, the water-snow ratios for different localities agree closely for the same dates.

The winter of 1903–4 was one of unusual and continued cold in New York and New England. The snowfall was very heavy and there was little rain and very few thawing days from December 1 to March 25.

In Table 3 are shown the results of a series of experiments made by the writer at Utica, N. Y., in the winter seasons of 1903–4 and 1904–5.

A level sodded plot in a city park was selected over which the snow was found by trial to lie quite uniformly. Large deciduous trees surround but do not overshadow the plot, near the center of which, and at successive points, a tin tube about three inches in diameter was thrust vertically downward and a cylinder of snow obtained, whose equivalent water depth was accurately determined by weight. A sample was taken each Monday to correspond with the weekly snow re-

Table 1.—*Water content of snow, Potsdam, Prussia, reduced to English units by Robert E. Horton.*[1]

Date.	Old snow cover.		Fresh snow cover.	
	Depth.	Water ratio.	Depth.	Water ratio.
(1)	(2)	(3)	(4)	(5)
1896.	*Inches.*		*Inches.*	
Jan. 1	3.54	0.17	0.75	0.08
Jan. 3	3.07	0.21	......	......
Jan. 5	0.87	0.35	......	......
Jan. 7	0.79	0.34	......	......
Jan. 8	1.14	......	0.16	0.18
Jan. 9	1.57	0.27	0.43	0.04
Jan. 10	2.76	......	0.83	0.06
Jan. 11	2.16	0.20	......	......
Jan. 12	1.57	......	0.79	0.07
Jan. 13	2.16	......	......	......
Jan. 16	2.79	0.16	1.22	0.18
Jan. 17	6.14	......	3.11	0.07
Jan. 18	5.12	0.21	......	......
Jan. 20	2.05	0.34	......	......
Jan. 22	1.77	0.26	......	......
Jan. 23	2.36	0.24	0.39	0.08
Jan. 26	3.15	......	1.57	0.07
Jan. 27	2.28	0.27	......	......
Jan. 29	3.19	......	0.16	0.08
Jan. 30	3.03	0.24	......	......
Feb. 15[2]	3.07	0.07	3.07	0.07
Feb. 16	2.13	0.10	......	......
Feb. 17	2.01	0.11	0.08	0.12
Feb. 18	1.50	0.16	......	......
Feb. 19	0.67	0.30	......	......
Feb. 28	0.28	0.03	0.28	0.03
Mar. 9[2]	0.79	0.12	0.79	0.12
Mar. 13[2]	0.08	0.31	0.08	0.31
Nov. 29[2]	0.20	0.10	0.20	0.10
Nov. 30	0.47	0.10	0.16	0.12
Dec. 16	1.18	0.07	1.18	0.07
Dec. 26	1.50	......	0.59	0.04
1897.				
Jan. 10[2]	0.315	0.08	0.315	0.08
Jan. 11	0.315	0.08	......	......
Jan. 12	0.197	0.16	......	......
Jan. 15	0.827	0.20	0.708	0.08
Jan. 16	1.496	0.12	0.551	0.03
Jan. 17	0.984	......	......	......
Jan. 22	0.0236	0.08	0.0236	0.08
Jan. 23	1.574	0.07	1.42	0.07
Jan. 24	3.740	......	3.15	0.11
Jan. 25	6.300	0.09	3.03	0.07
Jan. 26	6.850	......	1.30	0 07
Jan. 27	7.087	......	1.30	0.07
Jan. 28	9.645	0.12	2.36	0.08
Jan. 29	9.921	......	1.61	0.10
Jan. 30	9.606	0.14	0.906	0.07
Feb. 1	8.780	0.15	......	......
Feb. 3	8.858	......	1.22	0.18
Feb. 4	8.267	0.18	......	......
Feb. 7	10.236	......	2.76	0.11
Feb. 8	11.811	0.18	3.86	0.14
Feb. 11	9.646	0.22	......	......
Feb. 15	7.874	0.25	......	......
Feb. 18	6.968	0.30	......	......
Feb. 22	3.150	0.32	......	......
Mar. 7[2]	0.197	0.10	0.197	0.10
Nov. 25[2]	0.512	......	0.512	......
Nov. 27	0.787	0.10	0.787	0.10
Dec. 4	1.417	0.06	1.417	0.06
Dec. 23	0.236	0.10	0.236	0.10
1898.				
Feb. 5[2]	0.984	0.11	0.984	0.11
Feb. 7	4.33	0.08	1.50	......
Feb. 10	2.59	0.20	0.79	0.09
Mar. 6[2]	1.30	0.13	1.30	0.13
Nov. 25[2]	0.394	0 16	0.39	0.16
1899.				
Jan. 2[2]	0.63	0.22	0.63	0.22
Jan. 3[2]	3.35	0.13	3.35	0.13
Feb. 2[2]	0.197	0.08	0.197	0.08
Feb. 3	1.54	0.03	1.50	......
Feb. 6	0.59	0.05	0.236	......
Mar. 20[2]	0.59	0.05	0.59	0.05
Mar. 23[2]	0.197	0.04	0.197	0.04
Mar. 27[2]	0.118	0.15	0.118	0.15
Dec. 11[2]	0.866	0.06	0.866	0.06
Dec. 14	3.540	0.09	0.906	0.05
Dec. 18	5.710	0.13	0.590	0.17
Dec. 25	6.100	0.14	0.906	0.06
Dec. 27	7.240	0.14	......	......
Dec. 31	3.740	......	......	......
1900.				
Jan. 1	2.16	0.195	......	......
Jan. 12[2]	0.67	0.03	0.67	0.03
Jan. 15	0.71	0.045	0.32	......
Jan. 18	1.22	0.113	0.16	0.125
Jan. 31[2]	9.50	0.064	0.65	0.091
Feb. 9	3.74	0.189	......	......
Feb. 12	7.68	0.152	0.28	0.075
Feb. 15	8.47	0.180	0.20	0.105
Feb. 19	6.30	0.250	......	......
Mar. 2[2]	0.12	......	0.12	......
Mar. 5	0.28	......	0.20	0.100
Mar. 19[2]	0.32	0.182	0.32	0.19
Mar. 23[2]	0.12	0.067	0.12	0.0067
Average.	......	0.1526	......	0.0848

[1] Ergebnisse der Meteorologische Beobachtungen, Königl. Preuss. Meteorologische Institut, 1896–1900. Berlin.
[2] Old snow cover melted and new one formed since preceding record.

Table 2.—*Water equivalent of snow. Results of observations under the direction of N. C. Grover, made in New England during 1903–4. Compiled by H. K. Barrows, December, 1904.*

Date.	Depth of snow.	Water equivalent.	Ratio, water depth / snow depth.	Inches of snow per inch of water.	Locality
1900.	*Inches.*	*Inches.*			
March 17	38	10.49	0.276	3.62	Rumford Falls, Me.
March 31	20	9.84	0.492	2.03	Do.
1903.					
March 1	19	6.12	0.322	3.10	Do.
March 19	10	4.60	0.460	2.17	Madison, Me.
March —	10	8.00	0.800	1.25	Jackman, Me.
1904.					
January 29	15.75	2.35	0.149	6.71	Upper Dam, Me.
February 2	28	6.20	0.221	4.53	Jackman, Me.
February 3	24	5.12	0.213	4.69	Bartlett, N. H.[1]
February 4	20	4.16	0.208	4.81	The Forks, Me.
Do	16.5	3.25	0.197	5.08	Bretton Woods, N. H.
February 5	24	7.00	0.292	3.42	Danforth, Me.
Do	28	6.54	0.233	4.29	Oquossoc, Me.
February 6	22	6.70	0.305	3.28	North Woodstock, N. H.
February 7	27	4.03	0.149	6.71	Chesuncook, Me.[2]
February 8	20	5.20	0.260	3.85	Upper Dam, Me.
February 11	20	5.92	0.296	3.38	Roach River, Me.
February 26	32	4.83	0.151	6.62	Madison, Me.
February 29	18	4.33	0.240	4.17	The Forks, Me.
March 7	22	2.00	0.091	10.99	Bretton Woods, Me.
March 8	24	6.20	0.258	3.88	The Forks, Me.
Do	18	5.30	0.294	3.40	Do.
March 10	18	5.89	0.327	3 06	Bartlett, N. H.[3]
March 11	12	1.20	0.100	10.00	Chesuncook, Me.
Do	14	1.32	0.094	10.64	Do.
Do	16.5	1.44	0.087	11.49	Do.
April 18	10	4.30	0.430	2.32	Do.
April 20	9	3.54	0.394	2.54	The Forks, Me.
April 21	......	5.88	......	......	Roach River, Me.[4]

[1] Two inches of ice. [2] Light, frosty substance. [3] Snow, ice, and crust. [4] Grant farm. Depth of snow not given.

TABLE 3.—*Water equivalent of accumulated snow on ground at Utica, N. Y. Observed by Robert E. Horton.*

Date.	Depth of snow on ground.	Condition.	Equivalent water depth.	Ratio water depth / snow depth.	Inches snow per inch water.
1903.	*Inches.*		*Inches.*		
October 27	2.0				
November 15	T.				
December 9	18				
December 16	12.6		2.260	0.180	5.57
December 21	10.9		2.77	0.254	3.94
December 28	12.0		2.64	0.220	4.55
December 31	11.9		2.39	0.202	4.96
1904.					
January 2	13.0		2.39	0.184	5.44
January 5	19.0		3.52	0.186	5.39
January 11	13.0		3.56	0.274	3.65
January 19	19.0		3.65	0.192	5.20
January 25	21.0		5.28	0.251	3.98
February 1	21.5		4.92	0.229	4.37
February 8	18		6.165	0.342	2.92
February 15	22		6.42	0.292	3.42
February 22	20		6.67	0.333	3.00
February 29	22		6.04	0.275	3.64
March 2	21		6.04	0.287	3.48
March 7	18		7.42	0.413	2.42
March 11	15		4.52	0.301	3.32
March 14	13		4.67	0.260	2.78
March 21	14.5		5.92	0.408	2.45
March 25	5.5		1.65	0.300	3.33
1904.					
November 29	2.75	Dry, loose	0.25	0.09	11.11
December 5	1.0	....do	0.125	0.125	8.000
December 12	2.75	... do	0.25	0.09	11.11
December 19	4.5	....do	0.564	0.125	8.000
December 27	0.75	Ice	0.189	0.252	3.968
1905.					
January 3	5.0	Dry, light	0.628	0.126	7.936
January 9	6.75	....do	1.635	0.242	4.132
January 16	4	...do	1.131	0.283	3.533
January 23	2.25	Dry, ice bottom.	0.25	0.11	9.09
January 30	6	Dry	1.131	0.188	5.319
February 6	10	....do	2.389	0.238	4.201
February 13	19.25	Dry, settled	3.272	0.171	5.847
February 21	14.5	....do	3.272	0.226	4.424
February 28	12	....do	3.183	0.265	3.773
March 6	10.25	Damp	2.893	0.282	3.546

TABLE 4.—*Water equivalent of accumulated snow at Hancock, N. Y. D. B. Van Etten, Observer.*

Date.	Accumulated snow.	Water.	Ratio, water / snow.	Inches snow per inch water.
1905.	*Inches.*	*Inches.*		
January 2	2.5	0.42	0.168	5.952
February 6	16	1.85	0.116	8.620
February 14	18	2.93	0.163	6.134
February 20	20	3.49	0.124	8.064
February 27	10	2.45	0.245	4.081
March 6	9	2.40	0.267	3.745
March 13	5	1.30	0.260	3.846
March 20	4	1.35	0.338	2.958

TABLE 5.—*Water equivalent of accumulated snow, at Graefenberg reservoir, near Utica, N. Y. R. O. Salisbury, Observer.*

Date.	Accumulated snow.	Water.	Ratio, water / snow.	Inches snow per inch water.
1904.	*Inches.*	*Inches.*		
December 1	3.5	0.24	0.069	14.49
December 5	3.75	0.35	0.093	10.75
December 12	6.0	0.70	0.117	8.547
December 19	9.0	1.14	0.123	8.130
December 26	4.5	0.81	0.18	5.555
1905.				
January 1	3.5	0.87	0.249	4.016
January 9	8.5	1.98	0.233	4.291
January 16	7.0	1.88	0.27	3.703
January 23	8.5	2.38	0.28	3.571
January 30	10.0	2.61	0.261	3.831
February 6	17.0	5.06	0.295	3.389
February 13	20.0	5.97	0.298	3.355
February 20	22.0	6.25	0.285	3.508
February 27	22.5	7.30	0.325	3.076
March 6	24	6.66	0.28	3.571
March 13	21.5	6.03	0.281	3.558
March 20	14.5	4.88	0.336	2.976
March 27	8.5	3.37	0.397	2.518

ports of the U. S. Weather Bureau, and the actual depth of snow was also measured.

These measurements show nearly a continuous increase in the water equivalent of a foot of accumulated snow as the season advanced, and in general, an increase in depth of the snow layer was accompanied by an increase in the water equivalent per unit depth.

The heavy snow accumulation lying on the ground in March, 1904, was found to consist of strata of snow of varying compactness, nearly always with a half inch or more of nearly solid ice at the bottom, which should not be omitted in measuring. Measurements taken immediately preceding and again following a moderate rain, showed that the total rainfall had been added to the snow. The depth of the layer settled considerably as a result of the rain, so that the measurement taken just afterward showed the maximum snow-water ratio.

Similar records obtained at two other stations in New York during the winter 1904–5, are given in Tables 4 and 5.

All records indicate that for the heavy and persistent snow accumulations occurring in New York and New England a progressive growth in the water equivalent per inch of snow on ground will usually take place as the season advances due to compacting by wind, rain and partial melting, and to the weight of the superincumbent mass on the lower layers.

The water equivalent of compacted snow accumulation is commonly between $\frac{1}{3}$ and $\frac{1}{5}$ or at least double that for freshly fallen snow. It is believed that the water-snow ratios determined in one locality will apply approximately to any other locality where the temperature, depth of snow cover, and length of time it has lain on the ground are about the same.

The depth of snow on the ground at the end of each week, for about twenty-five stations in New York, is given on the snow and ice charts of the U. S. Weather Bureau.

Utilizing the water-snow ratios for Utica, a map has been prepared showing by isohydral lines the depth of water stored on the ground December 31, 1903, throughout the State of New York, representing precipitation during the calendar year 1903, but which became available to feed the streams during 1904. See fig. 3.

A very large percentage of accumulated snow subsequently appears as run-off in the stream, and it will be seen at once that in this locality the difference in water held on the ground as accumulated snow at the beginning and ending of any year, may be several inches; an important disturbing element in any attempt to correlate precipitation and flow of streams by calendar years.

The estimated average depth of water stored on the ground surface in New York in the form of snow, December 31, 1903, was 2.15 inches. On December 31, 1904, a large portion of the State was bare, while there were from one to eight inches of loose, dry snow elsewhere. It appears that about two inches of precipitation was thus added to the available supply for streams during 1904. As this water nearly all appears as run-off, it would cause an increase of one and one-half or two inches, or five to ten per cent in the run-off for the calendar year 1904 in excess of the amount resulting from the contemporaneous precipitation.

The agreement between the weekly precipitation measured as melted snow and the increment of accumulated snow is not very close. This may be for the reason that an ordinary rain gage does not properly register snowfall, or because the accumulated snow was of necessity measured in a protected place, whereas rain gages are usually exposed in the open. At Graefenberg reservoir, for example, the accumulated snow is measured in an opening in a small grove, while the precipitation is measured in an adjoining open field fully exposed to the wind, where the ground is nearly always bare. In January, 1905, the snow accumulated in the grove increased 1.74 inches. The total precipitation was 1.76 inches. In February, 1905, the snow storage increased 4.69 inches in the grove while the measured precipitation was only 0.54 inch. In general, however, the total precipitation is in excess of the snow

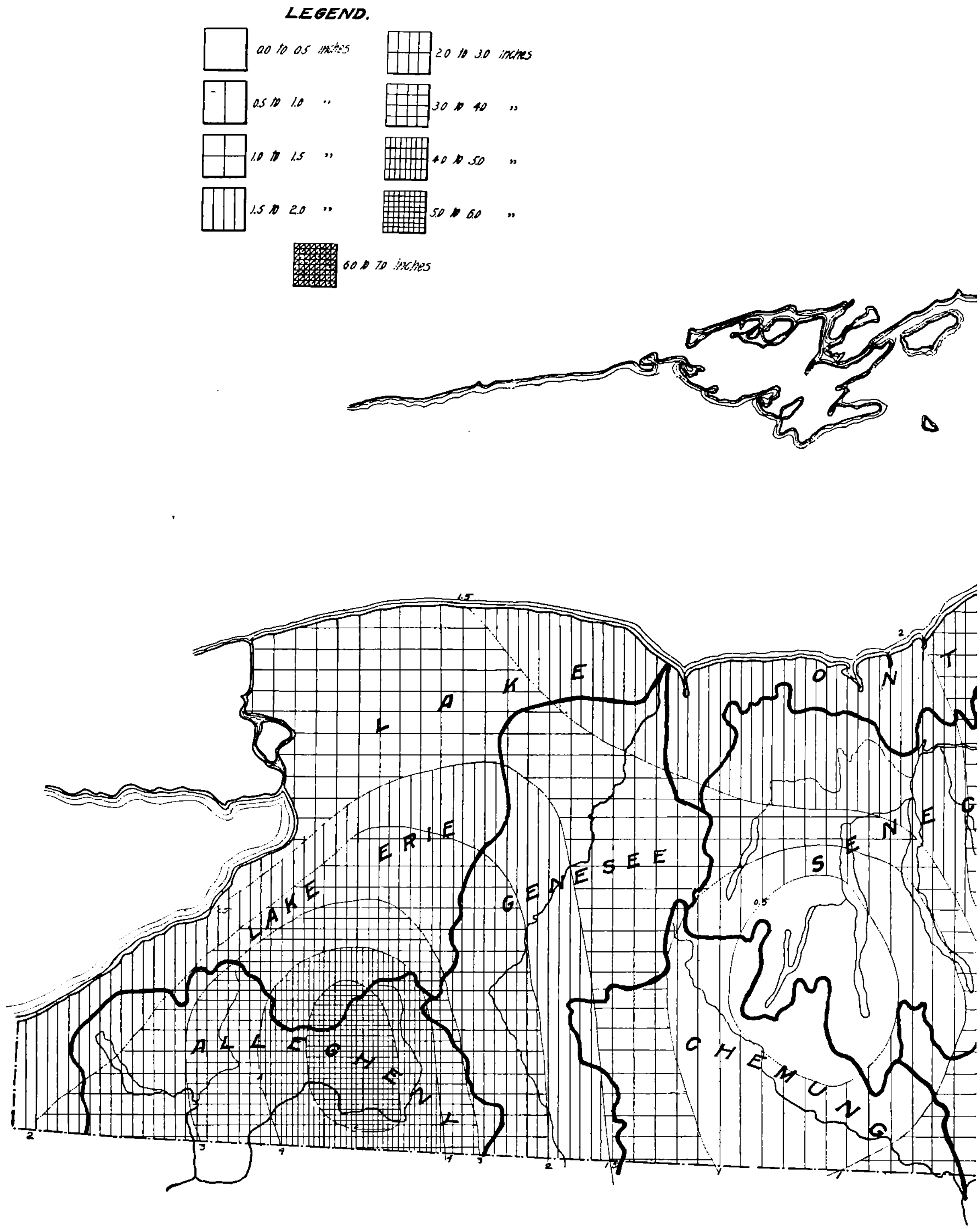
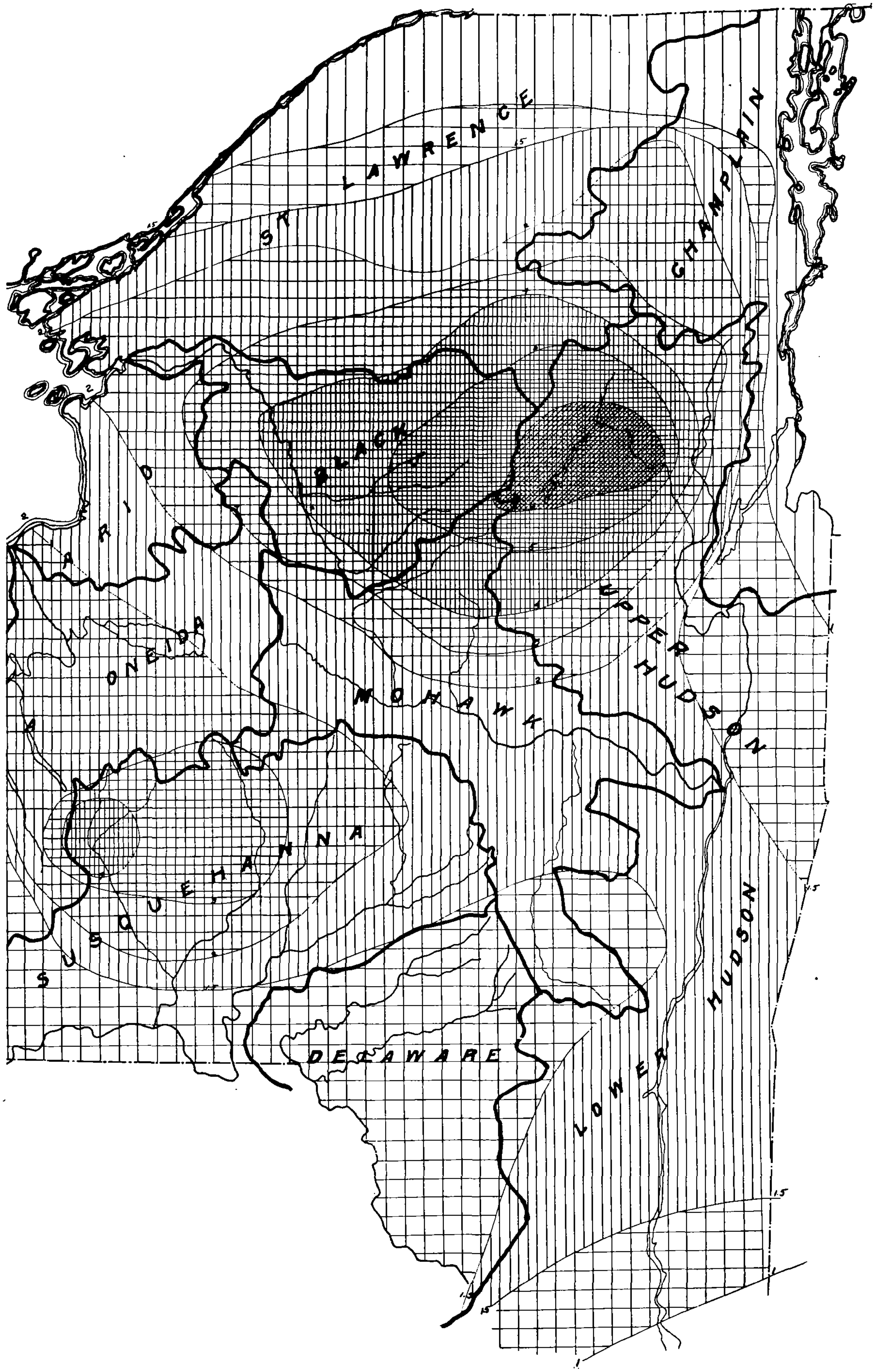


FIG. 1.—Water equivalent of snow on ground in New York, December



31, 1903. Contour lines bound areas of varying water depth in inches.

27——3

FIG. 2.—Winter meteorological conditions, Starch Factory Creek near Utica, N. Y.

storage, indicating a loss from the snow on ground through evaporation.

In conjunction with the meteorological records at Graefenberg reservoir, a weir was erected and a careful record kept of the flow of Starch Factory Creek. Referring to the diagram (fig. 2) it will be seen that during the period from December 1, 1903, to February 7, 1904, the temperature was almost constantly below 32°. There was no precipitation as rain, and it thawed but little. This being the case, the interesting conclusion arises that during this period of 69 days the entire supply to streams in this locality must have been from ground water, or lake or marsh storage, or from these sources combined.

There is no lake or marsh storage in this catchment basin. The snow cover in a very close winter season effectually cuts off all surface run-off into streams. Such a period affords therefore, in a basin without lakes or marshes, a ready means of determining the inflow to the stream from ground water. With this end in view, a record of the ground-water level in wells is also kept.

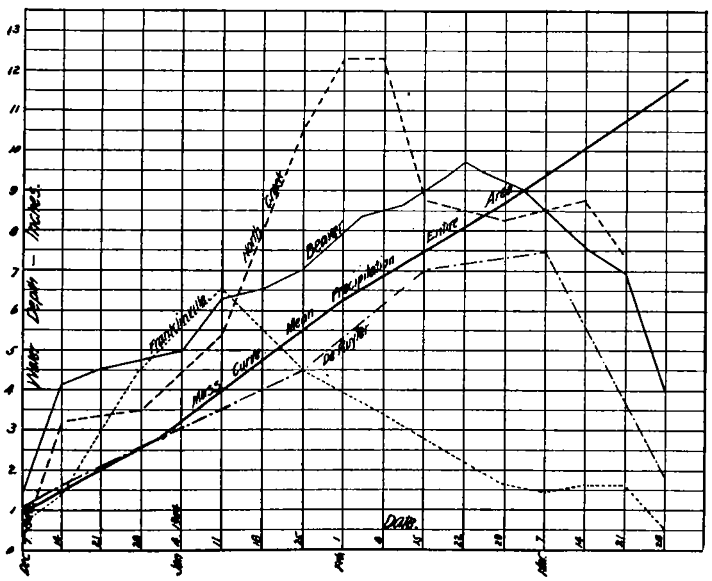


Fig. 3—Estimated water equivalent of accumulated snow on ground at points in New York State, winter of 1903–4.

The method of studying ground water is outside the scope of this paper. It may be mentioned in passing, however, that the winter season of 1903–4, occasioned the lowest known volume of flow in many New England streams; the cause, as above outlined, being the shutting off of the surface inflow from lakes and precipitation.

Fig. 2 clearly shows that the stream flow did not respond even to heavy precipitation (snowfall) at any time covered by the diagram, unless the temperature was above 32°. It appears that the winter flow of such a stream is much more nearly a function of the temperature than of the precipitation. The lack of direct relation between precipitation and run-off during the spring freshet season is even more marked, confirming the proposition that during the season of snow storage there is no direct relation between monthly precipitation and contemporaneous stream flow, inasmuch as water may be carried forward from the earliest snowfall to the spring freshet, in the form of surface storage. As a rule, any rise of temperature above 32° is accompanied by rise of the stream and by a diminution of the snow storage.

The lack of direct relation between precipitation and run-off during the winter season is further illustrated by the data given in Table 6, prepared from gagings under the writer's direction. The figures show the percentage relation between run-off of each month and the actual precipitation for the same month during the severe and snowy winter of 1903–4. Only a few cases are given out of a much larger number of observations.

On West Canada Creek area a precipitation of 10.61 inches in December, 1903, was accompanied by a run-off of 1.31 inches, or 12.35 per cent. In April, 1905, the same stream yielded 12.26 inches run-off, the contemporaneous precipitation being 3.72 inches, or less than one-third the run-off. The run-off continued in excess of the contemporaneous precipitation during two, three, or four months in the spring of 1903–4. In seasons of less snowfall the duration of the season of excess of run-off over precipitation is shorter, but the run-off invariably exceeds the rainfall during one or two spring months. This is illustrated by Table 7 giving the monthly precipitation and run-off of Mohawk River at Little Falls, N. Y., during several winter periods.

Table 6.—*Comparison of winter precipitation and run-off, winter of 1903-4.*

Stream.	Location.	Drainage area.	Method of gaging.	Character of basin.
		Sq. m.		
West Canada Creek.	Twin Rock, N. Y.	364	Current meter	Rugged, wooded.
East Canada Creek.	Dolgeville, N. Y.	256	Dam and mill	Rugged, semicleared.
Saranac River.	Plattsburg, N. Y.	624	Dam and mill	Wooded, many lakes.
Reel's Creek.	Utica, N. Y.	44	Weir.	Precipitous, sodded, no lakes.
Chenango River.	Binghamton, N. Y.	1534	Current meter.	Rolling, mostly cleared, no lakes.
Susquehanna River..	Binghamton, N. Y.	2400	Current meter.	Rolling, mostly cleared, few lakes.
Catskill Creek.	South Cairo, N. Y.	263	Current meter.	Precipitous, rocky, mostly wooded.
Oneida River.	Scrœppels Bridge, N. Y.	1313	Current meter	Flat, large lake area.

Table 6, cont'd.—*Percentage of rainfall appearing in stream as run-off.*

Month.	West Canada Creek.	East Canada Creek.	Saranac River.	Reel's Creek.	Chenango River.	Susquehanna River.	Catskill Creek.	Oneida River.
December, 1903	12.35	73.2	39.2	29.1	43.6	115.	53.	47
January, 1904..	29.47	38.0	34.1	19	61.4	84	98	40
February, 1904.	36.34	35.0	54.1	25	183.6	207	228	102
March, 1904....	162.1	82.7	233.7	296	281	162	197	166
April, 1904.....	329.6	255.	113.2	298	152	173	97	224
May, 1904......	189.2	154.3	116.2	48.7	50.7	60.7	44.5	165

Table 7.—*Comparison of winter precipitation and run-off, Mohawk River at Little Falls, N. Y. Drainage area, 1306 square miles. Depths are in inches for the whole catchment area.*

Months.	1898–9.		1899–1900.		1900–1901.		1901–2.		1902–3.		1903–4.	
	Precipitation.	Run-off.	Precipitation.	Run-off.	Precipitation.	Run-off.	Precipitation.	Run-off.	Precipitation.	Run-off.	Precipitation.	Run-off.
November...	4.72	2.46	2.84	1.45	6.96	3.30	4.42	1.38	2.31	2.21	2.63	1.46
December...	4.20	1.74	4.09	2.69	3.48	2.85	4.91	3.47	4.38	2.95	4.52	1.32
January.....	2.83	2.35	4.02	4.86	3.09	1.53	1.50	1.27	3.47	1.90	4.16	1.20
February....	2.56	1.19	3.93	5.08	2.37	0.89	4.08	0.94	3.08	2.87	2.91	1.88
March.......	5.27	3.32	6.12	2.18	3.15	4.02	4.22	8.34	5.88	9.54	3.21	5.07
April........	2.03	6.92	1.49	6.95	3.13	6.06	3.04	3.00	2.13	3.56	3.28	7.01
May.........	3.77	2.34	2.24	1.82	5.16	2.53	3.88	2.33	0.15	0.67	3.74	3.36

During the winter season, when the soil surface is frozen and covered with snow, the flow in streams is comparatively steady. The wide variations appearing in the percentages of Table 6 for the months of December, January, and February are chiefly due to the varying precipitation during the different months.

There are a number of considerations in addition to snow storage which may tend to increase the apparent rainfall run-off ratio during the winter season.

(1) The stream gagings may be in excess, due to the accumulation of ice on dams or in streams, causing backwater. This is not true in the cases observed in April and May, and it is believed it does not materially affect any of the results here given.

It will be noted that gagings made by different methods, weirs, dams, mills, and by current meter, all lead to the same result, namely, the measured run-off during the winter season nearly equals and sometimes for several months exceeds the measured precipitation at nearby stations.

(2) The ground-water level is nearly always drawn down considerably in the course of a long, cold winter; hence, there should be added to the possible supply to the stream from direct precipitation the amount drawn from ground-water storage during the winter. In the case of areas like those listed in Table 6 it is not very large, probably not more than one or two inches, as a maximum.

(3) Regarding the measurement of winter precipitation, the U. S. Weather Bureau stations are mostly located in the valleys and at other than the highest elevations. The measured precipitation, even if correctly determined at these stations, would probably be somewhat deficient, as precipitation increases with altitude in many localities.

(4) The measurement of snowfall by catching it in a rain gage, in the same manner as rain, is likely to give deficient results inasmuch as the rain gage offers an obstruction and deflects the air currents. The snowflakes, owing to their small specific gravity, as compared with raindrops, do not enter the mouth of the gage, but are diverted to the side or carried over by the wind. This source of error is aggravated by the fact that nearly all the U. S. Weather Bureau rain gages are at considerable distances above ground and mostly in very open locations fully exposed to the wind.[1]

(5) As to distribution of snowfall, even though the snowfall were correctly measured at the points where the U. S. Weather Bureau stations are located, it can easily be seen that the results might not represent correctly the average snowfall even in the immediate locality. This was graphically illustrated at a rain-gage station in the Mohawk Valley last winter. The gage in question was located in the open, surrounded by cultivated fields. With some precaution the depth of snow which actually fell in the immediate vicinity of the gage was determined with fair accuracy. At no time in winter did the snow on the ground near the gage accumulate to a depth exceeding about one foot. The adjacent country comprises deep valleys occupied by streams, patches of woodland, and also clearings similar to that containing the gage. In the woodland and valleys within one-fourth mile of the rain gage, snow accumulated to a depth of three or four feet; thus it will be seen that the snowfall measured in the clearing, under conditions similar to those existing at many U. S. Weather Bureau stations, would represent very much less than the average of the entire region, including the woodland, valleys, and clearing, although it might be quite accurate as regards the snow that fell on the clearing itself.

With regard to the question whether the existing rainfall stations truly represent the average precipitation on the drainage basins, it may be said that the summer season rainfall-run-off ratios for these streams conform closely to existing notions, and it appears that the effect of this error, if any, is greatly exceeded by the other conditions described.

[1] For a number of years past the Weather Bureau has entirely disregarded gage measurements of snowfall whenever there was reason to believe that the gage was not collecting the full amount of fall. At such times measurements are made in some level place where it is apparent that an average depth can be obtained.—*H. C. F.*

The maximum flood discharge on northern streams may result chiefly from melting snow, accompanied by more or less rainfall.

TABLE 8.—*Melting-snow freshet, March, 1904; yield of small catchment areas near Utica, N. Y.*

Stream.	Drainage area, square miles.	Duration of freshet.			Average discharge in cubic feet per square mile per second.	Total yield during freshet. Depth run-off.
		From —	To —	Days.		
						Inches.
Starch Factory Creek	3.40	March 22,	March 29,	7	33.33	8.67
Reels Creek	4.42	March 24, noon,	March 29, noon.	5	29.92	5.56
Sylvan Glen Creek	1.18	March 22, noon,	March 27, noon.	5	19.06	3.55

Table 8 shows the run-off of Mohawk River and a number of its tributaries in March, 1904, during the melting-snow freshet. None of these streams have lake storage. The contemporaneous rainfall is shown in Table 9.

TABLE 9.—*Precipitation during spring flood, 1904, upper Mohawk River catchment area.*

Date.	Little Falls.	Savage reservoir.	Deerfield reservoir.	Rome.
March 21				0.20
March 22		0.07	0.72	0.30
March 23	0.71	0.61		
March 24				
March 25	0.35	0.05		0.20
March 26	0.18	0.23	0.45	0.33
March 27				
March 28				
March 29				
March 30				
March 31	0.08	0.35	0.45	0.15

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R. A. EDWARDS, Acting Librarian.

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